Large two-pion-exchange contributions to the $pp \to pp\pi^0$ reaction

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Abstract

The large two-pion exchange amplitudes are calculated in HBχPT and their net contribution to the reaction cross section is large.

Refs. [1, 2] evaluated this reaction at threshold in HBχPT. They found that the impulse approximation (I.A.) and one-pion-exchange (Resc) diagrams interfere destructively resulting in a very small reaction cross section. According to Lee and Riska [3] a model explanation of the measured reaction cross section near threshold requires the contributions from heavy meson (σ and ω) exchange in addition to the one-pion-exchange. The σ-meson-exchange is more properly described by correlated two-pion-exchange. This knowledge prompted a HBχPT study of two-pion-exchange (TPE) contributions to the $pp \to pp\pi^0$ reaction amplitude [4].

In Weinberg chiral counting the TPE contributions are of higher chiral order in HBχPT. However, it was shown by Ref. [4] that some TPE amplitudes are as large or larger than the lower chiral order Resc contribution. At threshold the typical momentum is $p \sim \sqrt{m_\pi m_N}$. This large momentum prompted Cohen *et al.* [2] to propose a momentum counting rule, reviewed in Ref. [5]. According to this counting, one finds that the Resc diagram is higher order in p/Λ compared to some "dominant" TPE diagrams, and this counting agrees with the numerical evaluations of the TPE diagrams of Ref. [4]. One drawback with the momentum counting is that the sum of the diagrams in each "momentum order" no longer is independent of the definition of the pion field. Hanhart and Kaiser (HK) [6] used momentum counting to evaluate the "leading" momentum behavior of the dominant TPE diagrams. HK also found that diagram II in Ref. [4] should have opposite sign (which we confirmed), and they found that the sum of the leading momentum behavior of the three dominant TPE diagrams cancel. We will present results from Ref. [4] and a recent calculations [7] which

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show that the "sub-leading" parts of a dominant TPE diagram gives a contribution comparable to the Resc amplitude.

The TPE transition operators (TO) were evaluated analytically by Ref. [4] in HBχPT. When these operators are sandwiched between phenomenologically determined distorted NN wave functions, the momentum integrals converge slowly [7]. This slow convergence can be understood when we adopt the threshold fixed kinematics approximation (FKA). Imposing FKA on the analytic expressions for the TO given in Ref. [4], we make an asymptotic expansion in the two-nucleon momentum transfer ($|\vec{k}| = |\vec{p} - \vec{p}\,'| \to \infty$). The TO matrix T of the TPE diagrams is of the form

$$T = \left(\frac{g_A}{f_\pi}\right) \left(\vec{\Sigma} \cdot \vec{k}\right) t(p, p', x)$$

where $x = \hat{p} \cdot \hat{p}'$. The *asymptotic* momentum behavior for $t(p,p',x)$ is $t(p,p',x) \sim t_1\, |\vec{k}| + t_2 \ln[\Lambda^2/|\vec{k}|^2] + t_3 + \delta t(p,p',x)$, where $\delta t(p,p',x)$ is $\mathcal{O}(|\vec{k}|^{-1})$, and the amplitudes t_i, $i = 1, 2, 3$ are known analytic expressions for each diagram. The t_1 amplitude is the dominant TPE amplitude of HK [6].

Amplitude K =	I	II	III	IV	V	VI	VII
R_K	$-.70$	-6.70	-6.70	9.50	0.18	0.14	2.65
$t_1 \quad \propto$	$-$	-2	-1	$+3$	$-$	$-$	$-$

In the table the row marked R_K, gives the values of the ratio of TO to the Resc amplitude in the plane wave approximation for the seven amplitudes of Ref. [4]. As indicated in the last row of the table, marked t_1, the leading momentum terms of the TO from diagrams II, III and IV sum to zero, confirming HK's result [6]. The non-cancellation of the dominant amplitudes can however be inferred from the R_K row since the ratios II:III:IV are not -2:-1:3 but roughly -2:-2:3. When we remove t_1, we find that the sum of the two-pion-exchange amplitudes is larger than the Resc amplitude [7].

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References

[1] B.-Y. Park *et al.*, Phys. Rev. **C 53**, 1519 (1996)

[2] T.D. Cohen *et al.*, Phys. Rev. **C 53**, 2661 (1996)

[3] T.-S.H. Lee and D.O. Riska, Phys. Rev. Lett. **70**, 2237 (1993)

[4] V. Dmitrašinović *et al.*, Phys. Lett. **B 465**, 43 (1999).

[5] C. Hanhart, Phys. Rep. **397**, 155 (2004)

[6] C. Hanhart and N. Kaiser, Phys. Rev. **C 66**, 054005 (2002).

[7] Y. Kim, K. Kubodera, F. Myhrer and T. Sato, in preparation.